CLAIMS:

1. A semiconductor device with a conductive element and a current sensor, wherein the current sensor is a magnetic current sensing device for sensing direct, varying or alternating current flowing through the conductive element, the current sensing device being integrated in the semiconductor device and being galvanically isolated from the conductive element.

2. A semiconductor device according to claim 1, suitable for measuring current with a μA resolution.

3. A semiconductor device according to any of the previous claims, wherein the current sensing device comprises at least one TMR device.

4. A semiconductor device according to claim 3, wherein the current sensing device shares an MTJ stack with an MRAM device.

5. A semiconductor device according to claim 4, wherein the MTJ stack comprises:

- an electrically insulating material (103) designed to form a magneto-resistive tunnelling barrier,
- a pinned magnetic region (105) positioned on one side of the electrically insulating material (103), the pinned magnetic region (105) having a magnetic moment vector adjacent the electrically insulating material (103),
- a nearly balanced free magnetic region (220) positioned on an opposite side of the electrically insulating material (103), the free magnetic region (220) having a magnetic moment vector (222) adjacent the insulating material (103) and oriented in a position parallel or anti-parallel to the magnetic moment vector of the pinned magnetic region (105), the free magnetic region (220) including an artificial anti-ferromagnetic layer material including N ferromagnetic layers (F1, F2) which are antiferromagnetically coupled, where N is an integer greater than or equal to two.

6. A semiconductor device according to any of claims 3 to 5, wherein the current sensing device has a free magnetic layer which has an easy axis oriented to be substantially perpendicular to a magnetic field caused by current under measurement.

7. A semiconductor device according to claim 6, the current sensing device having an easy axis, wherein the easy axis of the free layer is caused by shape elongation.

8. A semiconductor device according to any of claims 3 to 7, wherein the current sensing device is subjected to an additional magnetic field that can either be direct, varying or alternating.

9. A semiconductor device according to any of the previous claims, the current sensing device having a pinned magnetic layer with a magnetisation direction and a free magnetic layer having an easy axis, wherein the magnetisation direction of the pinned magnetic layer is oriented at an angle, with the easy axis of the free magnetic layer, preferably between 45° and 135°, more preferred substantially perpendicular to the easy axis of the free magnetic layer.

10. A semiconductor device according to any of the previous claims, the semiconductor device comprising adjacent a first side of the current sensing device (210) a first conductor (90) for conveying a current (I_x) to be measured and adjacent a second side of the current sensing device (210) a second conductor (91) for conducting current (I_2), the first conductor (90) and the second conductor (91) crossing but not being electrically connected.

11. A semiconductor device according to claim 10, the free magnetic layer of the current sensing device (210) having an easy axis, wherein the first conductor and the second conductor each include an angle of substantially between 30° and 90° with respect to the easy axis of the current sensing device.

12. A semiconductor device according to claim 10, furthermore comprising a feedback circuit (80) for measuring MR changes on the current sensing device (210) and for controlling current (I2) in the second conductor (91) in such a way that no MR change is observed on the current sensing device (210).

13. A semiconductor device according to claim 12, wherein the current feedback circuit has means for generating a feedback signal indicative of the current (I_x) to be measured and conveyed by the first conductor (90).

14. A semiconductor device according to any of claims 10 to 13, wherein at least one of the first conductor (90) and the second conductor (91) comprises at least one vertical conduction component and at least one horizontal conduction component, there being a corner between the vertical conduction component and the horizontal conduction component, thus forming a conductor structure which at least includes an L-shaped part of which the corner is located adjacent the current sensing device.

15. A semiconductor device according to any of the previous claims, furthermore comprising a flux-concentrator (50; 70) to increase the magnetic field at the location of the current sensing device (210).

16. A semiconductor device according to claim 15, wherein the flux-concentrator (50; 70) comprises a dummy MTJ stack which is patterned around at least one vertical conduction component.

17. A semiconductor device according to claim 15, wherein the flux-concentrator (50; 70) is ring-shaped and comprises a gap (51) between poles, the current sensing device (210) being located in the gap (51).

18. A semiconductor device according to any of the previous claims, wherein the sensor device is compatible with CMOS or MOS processing.

19. A semiconductor device according to any of the previous claims, wherein the semiconductor device is an integrated circuit.

20. A semiconductor device according to claim 19, wherein the current sensor or sensors are arranged to sense quiescent currents (IDDQ) or transient currents (IDDT).

21. Use of an integrated magnetic current sensing device which is galvanically not in contact with a conductive element, for sensing at least a direct, a varying or an alternating current flowing through the conductive element, wherein the sensing device is used for on-chip measurement of current.

22. Use of an integrated magnetic current sensing device according to claim 21, for sensing quiescent currents (IDDQ) or transient currents (IDDT).

23. A method for sensing current in a conductor in a semiconductor device, wherein the method comprises sensing a direct, a varying or an alternating current flowing in the conductor by performing contactless magnetic current sensing with a sensor integrated on the semiconductor device.

24. A method according to claim 23, wherein the method comprises sensing a magnetic field caused by the current.

25. A method according to claim 23 or 24, wherein the method comprises measuring current in at least one processing module.

26. A method according to claim 25, wherein the method comprises controlling the clock speed of at least one processing module to obtain a matching with a pre-defined current consumption level.

27. A method according to any of claims 23 to 26, wherein the method comprises the measurement of current consumption and the generation of a warning signal if a set current consumption threshold is superseded.

28. A method according to any of claims 23 to 27, wherein a software based routine performs job scheduling over several processing units based on the measured currents that invoke either an interrupt or a register bit to be set.

29. A software product which when executed on a processing device performs job scheduling over several processing units based on measured currents that invoke either an interrupt or a register bit to be set.

30. A method for manufacturing a semiconductor device according to any of claims 3 or 4, the method comprising providing an MTJ stack.

31. A method according to claim 30, wherein providing the MTJ stack comprises depositing a free region.

32. A method according to claim 31, wherein depositing a free region comprises depositing an artificial anti-ferromagnetic free region comprising a plurality of anti-ferromagnetically coupled ferromagnetic layers.

33. A method according to claim 32, the artificial anti-ferromagnetic free region having a net magnetic moment which is substantially zero, the method furthermore comprising modifying the net magnetic moment of the free region so as to make it non-zero.